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Study of T and CP violation in $B^0\overline{B}^0$ mixing with inclusive dilepton events

The *BABAR* Collaboration

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Abstract

We report a study of T and CP violation in $B^0\overline{B}^0$ mixing using an inclusive dilepton sample collected by the *BABAR* experiment at the PEP-II B Factory. The asymmetry between $\ell^+\ell^+$ and $\ell^-\ell^-$ allows us to compare the probabilities for $\overline{B}^0 \to B^0$ and $B^0 \to \overline{B}^0$ oscillations and thus probe T and CP invariance.

A sample of 20,381 same-sign dilepton events is selected in the 1999–2000 data sample, corresponding to an integrated luminosity of 20.7 fb^{-1} on the $\Upsilon(4S)$ resonance. We measure a same-sign dilepton asymmetry of $A_T = (0.5 \pm 1.2 \pm 1.4)\,\%$; for the parameter ε_B representing T and CP violations in mixing, we obtain a preliminary result of

$$\frac{\mathrm{Re}(\varepsilon_{\mathrm{B}})}{1+|\varepsilon_B|^2} = (1.2 \pm 2.9 \pm 3.6) \times 10^{-3}.$$

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1 Introduction

Since the first discovery of *CP* violation in 1964 [1], the kaon system has provided many other results probing the *CPT* and *T* discrete symmetries [2]. The *BABAR* experiment is not limited to an investigation of *CP* violation through the measurement of $\sin(2\beta)$ or the angle α; in a similar way as for kaon system studies, it is also possible to investigate *CP* violation purely in mixing and disentangle whether this *CP* violation is due to *T* or *CPT* violation.

In this document, we have adopted a formalism very similar to that used for the kaon system [3]. In the absence of a *CP* phase, we can define the *CP* eigenstates $|B_1^0\rangle$ and $|B_2^0\rangle$ as

$$
\begin{aligned}
|B_1^0\rangle &= \frac{1}{\sqrt{2}}\big(|B^0\rangle + |\overline{B}^0\rangle\big),\\
|B_2^0\rangle &= \frac{1}{\sqrt{2}}\big(|B^0\rangle - |\overline{B}^0\rangle\big).
\end{aligned}
$$

The physical states (solutions of the effective Hamiltonian) can be written as

$$
\begin{aligned}
|B_L^0\rangle &= \frac{1}{\sqrt{1+|\varepsilon_B+\delta_B|^2}}\big[|B_1^0\rangle + (\varepsilon_B+\delta_B)|B_2^0\rangle\big],\\
|B_H^0\rangle &= \frac{1}{\sqrt{1+|\varepsilon_B-\delta_B|^2}}\big[|B_2^0\rangle + (\varepsilon_B-\delta_B)|B_1^0\rangle\big].
\end{aligned}
$$

In the case of *CPT* and *CP* invariance, δ_B is equal to 0. Similarly, *T* and *CP* invariance gives $\varepsilon_B = 0$. This means that *CP* violation in mixing requires either $\varepsilon_B \neq 0$ or $\delta_B \neq 0$. Inclusive dilepton events in *BABAR* provide a very large sample with which to study *CP* violation in mixing and test *T* and *CPT* conservation. The semileptonic (muon or electron) branching fraction of B mesons is about 20%. Therefore, dilepton events represent 4% of all $\Upsilon(4S) \to B\overline{B}$ decays. The flavor of the B is tagged by the sign of the lepton. Assuming *CP* invariance in direct semileptonic decays, the asymmetry between same-sign dilepton pairs, $\ell^+\ell^+$ and $\ell^-\ell^-$, allows a comparison of the two oscillation probabilities $P(\overline{B}^0 \to B^0)$ and $P(B^0 \to \overline{B}^0)$ and therefore probes *T* and *CP* invariance:

$$
A_T(\Delta t) = \frac{P(\overline{B}^0 \to B^0, \Delta t) - P(B^0 \to \overline{B}^0, \Delta t)}{P(\overline{B}^0 \to B^0, \Delta t) + P(B^0 \to \overline{B}^0, \Delta t)} \approx \frac{4\mathrm{Re}(\varepsilon_\mathrm{B})}{1+|\varepsilon_B|^2}. \tag{1}
$$

This asymmetry[1] does not contain the *CPT* violation parameter δ_B to first order. For this asymmetry to be different from zero both *T* and *CP* violation in mixing are required. In the approximation that $|\Gamma_{12}| << |M_{12}|$, $A_T = \mathrm{Im}(\Gamma_{12}/M_{12})$ where $M_{12} - \frac{1}{2}i\Gamma_{12}$ is the off-diagonal element of the complex effective Hamiltonian for the B^0- $\overline{B}^0$ system. Standard Model calculations [5] predict the size of this asymmetry to be of order $(0.5 - 5.0) \times 10^{-3}$. Therefore, a large measured value for this asymmetry could be an indication of new physics.

The measurement of A_T reported here is performed using events collected by the *BABAR* detector at the PEP-II asymmetric B Factory between October 1999 and October 2000. The integrated luminosity of this sample is 20.7 fb^{-1} taken on the $\Upsilon(4S)$ resonance ("on-resonance") and 2.6 fb^{-1} taken 40 MeV below the resonance ("off-resonance"). The *BABAR* detector and its performance are described elsewhere [6].

[1]In another formalism [4], the physical states are related to the B^0 flavor eigenstates by $|B_L^0\rangle = p|B^0\rangle + q|\overline{B}^0\rangle$ and $|B_H^0\rangle = p|B^0\rangle - q|\overline{B}^0\rangle$ where p and q are complex mixing parameters with the normalization $|p|^2 + |q|^2 = 1$. The charge asymmetry in terms of $|q/p|$ is therefore equal to $A_T = (1 - |q/p|^4)/(1 + |q/p|^4)$.

The organization of this paper is as follows. The particle identification and event selection are described in Sec. 2. In particular, this section shows how cascade leptons from charm decays from charged B or unmixed neutral B events are rejected with a neural network (NN) approach and a Δz cut at $200\,\mu$m. The method to correct the charge asymmetry in the detection of the leptons is explained in Sec. 3. Finally, Sec. 4 shows the details of the fit on data and gives the evaluation of systematic uncertainties. To avoid the possibility of bias, both the time distribution of the charge asymmetry and the number of positive and negative same-sign dileptons are blinded during the analysis. The unblinding of the A_T measurement is performed once all studies of systematic uncertainties are finished.

2 Selection of dilepton events

In this study of T and CP asymmetries, the flavor of the B meson at the time of its decay is determined by the sign of direct leptons produced in semileptonic B decays. This section describes the selection of leptonic tracks and the rejection of cascade leptons.

2.1 Lepton identification

Lepton candidates must have a distance of closest approach to the nominal beam position in the transverse plane less than 1 cm, a distance of closest approach along the beam direction less than 6 cm, at least 12 hits in the Drift Chamber (DCH), at least one z-coordinate hit in the Silicon Vertex Tracker (SVT), and a momentum in the $\Upsilon(4S)$ center-of-mass system (CMS) between 0.7 and 2.3 GeV/c.

Electrons are selected by specific requirements on the ratio of the energy deposited in the Electromagnetic Calorimeter (EMC) and the momentum measured in the DCH, on the lateral shape of the energy deposition in the calorimeter, and on the specific ionization density measured in the DCH. Muons are identified through the energy released in the calorimeter, as well as the strip multiplicity, track continuity and penetration depth in the Instrumented Flux Return (IFR). Lepton candidates are rejected if they are consistent with a kaon or proton hypothesis according to the Cherenkov angle measured in the Detector of Internally Reflected Cherenkov Light (DIRC) and to the ionization density measured in the DCH.

The performance and charge asymmetry of the lepton selection are determined with data control samples, as a function of the particle momentum as well as the polar and azimuthal angles. The electron and muon selection efficiencies are about 92% and 75%, with pion misidentification probabilities around 0.2% and 3%, respectively. All corrections of the charge asymmetry in the identification of leptons are discussed in Sec. 3.

2.2 Background rejection

Non-$B\overline{B}$ events are suppressed by requiring the Fox-Wolfram ratio of second to zeroth order moments [7] to be less than 0.4. In addition, the residual contamination from radiative Bhabha and two-photon events is reduced by requiring the squared invariant mass of the event to be greater than 20 $(\,\mathrm{GeV}/c^2)^2$, the event aplanarity to be greater than 0.01, and the number of charged tracks to be greater than four.

Electrons from photon conversions are identified and rejected with a negligible loss of efficiency for signal events. Leptons from J/ψ and $\psi(2S)$ decays are identified by pairing them with other oppositely-charged candidates of the same lepton species, selected with looser criteria. We reject

the whole event if any combination has an invariant mass within $3.037 < M(\ell^+\ell^-) < 3.137\,\mathrm{GeV}/c^2$ or $3.646 < M(\ell^+\ell^-) < 3.726\,\mathrm{GeV}/c^2$.

2.3 Selection of direct dileptons

To minimize the dilution due to wrong-sign leptons from cascade charm decays (produced in $b \to c \to \ell$ transitions), we use a NN algorithm that combines five discriminating variables. These are calculated in the CMS and are

- the momenta of the two leptons with highest momentum, p_1^* and p_2^*;
- the total visible energy E_{tot} and the missing momentum p_{miss} of the event; and
- the opening angle between the leptons, θ_{12}.

The distributions of these variables are shown in Fig. 1, for data and Monte Carlo simulation. The first two variables, p_1^* and p_2^*, are very powerful in discriminating between direct and cascade leptons. The last variable, θ_{12}, efficiently removes direct-cascade lepton pairs coming from the same B and further rejects photon conversions. Some additional discriminating power is also provided by the other two variables. The NN architecture (5:5:2) consists of three layers, with two outputs in the last layer, one for each lepton in the event. The network is trained with 40,000 dileptons from generic Monte Carlo $B^0\overline{B}^0$ and B^+B^- events. The outputs are chosen to be 1 and 0 for direct and cascade leptons, respectively. The same network is used for both electron and muon selection. We require both outputs to be greater than 0.8.

2.4 Background rejection based on Δz information

In the inclusive approach used here, the z coordinate of the B decay point is the z position of the point of closest approach between the lepton candidate and an estimate of the $\Upsilon(4S)$ decay point in the transverse plane. The $\Upsilon(4S)$ decay point is obtained by combining the beam spot constraint and the relative position of the two lepton tracks. The time difference Δt between the two B mesons is determined from the difference in z between the two B's by $\Delta t = \Delta z / \langle\beta\gamma\rangle c$, where $\langle\beta\gamma\rangle \approx 0.56$.

To measure A_T, we want to select mixed events (B^0B^0 or $\overline{B}^0\overline{B}^0$ pairs) whose time dependence varies as $e^{-\Delta t/\tau_{B^0}}\,[1-\cos(\Delta m_d \Delta t)]$. The main sources of background (cascade leptons from unmixed $B^0\overline{B}^0$ events and B^+B^- events) vary respectively as $\sim e^{-\Delta t/\tau_{B^0}}\,[1+\cos(\Delta m_d \Delta t)]$ and $\sim e^{-\Delta t/\tau_{B^\pm}}$ (see Fig. 2). Therefore, a requirement of $\Delta z > 200\,\mu\mathrm{m}$ allows us to eliminate a large fraction of background without dramatically decreasing the signal efficiency. A Δz cut is also effective at removing backgrounds such as non-$B\overline{B}$ events or J/ψ decays. Finally, in the measurement of A_T, the dilution factor due to remaining background will be corrected as a function of Δz.

2.5 Event yields and sample composition

Application of the selection criteria described above results in a sample of 20,381 same-sign dilepton events, consisting of 5,252 electrons pairs, 5,152 muons pairs and 9,977 electron-muon pairs.

The fraction of non-$B\overline{B}$ events, measured with the off-resonance data, is 4.3% with a charge asymmetry of $(-5 \pm 10)\%$.

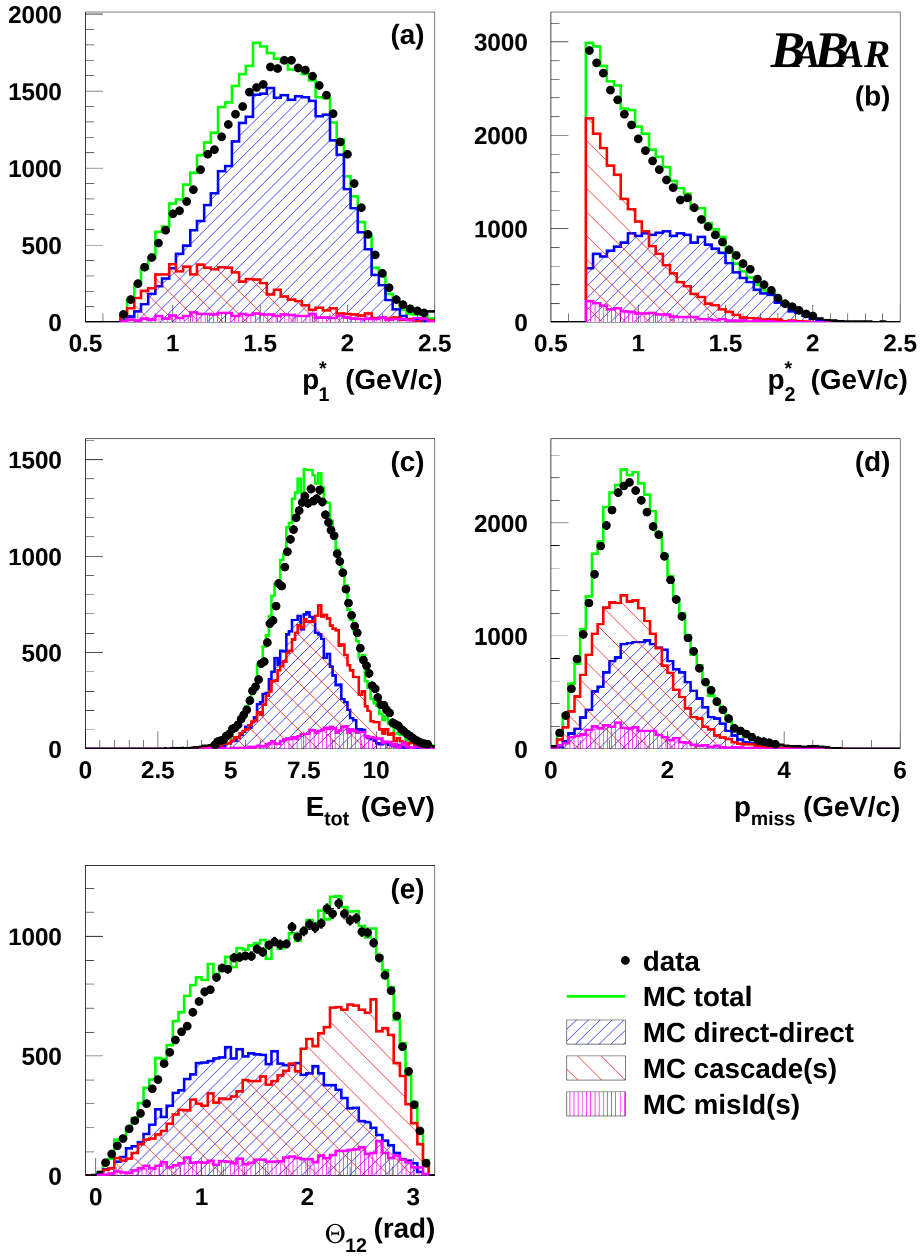

Figure 1: Distributions of the discriminating variables (a) p_1^*, (b) p_2^*, (c) E_{tot}, (d) p_{miss} and (e) θ_{12}, for data (points) and Monte Carlo events (histograms). The contributions from direct-direct pairs, direct-cascade or cascade-cascade pairs, and pairs with one or more fake leptons are shown for the Monte Carlo samples.

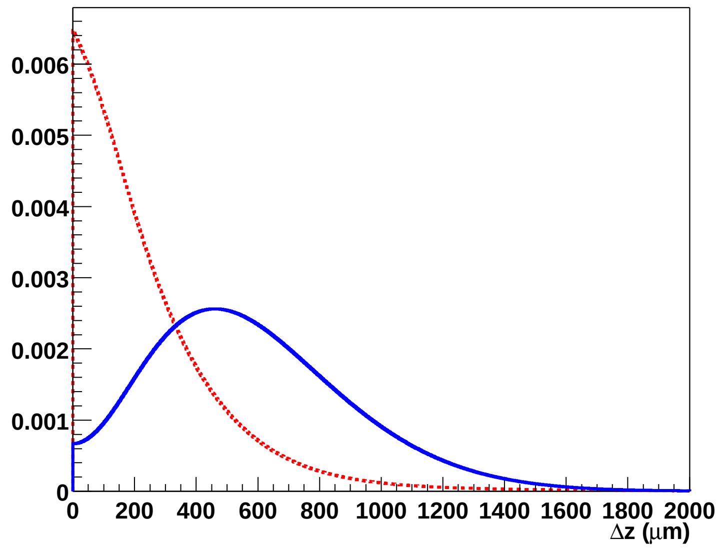

Figure 2: Probability density functions determined from a fit to the data with the value of Δm_d fixed to the world average value [8], for the signal (B^0B^0 or $\overline{B}^0\overline{B}^0$ pairs) (solid line) and the background (cascade from unmixed $B^0\overline{B}^0$ and B^+B^- events, and non-$B\overline{B}$ events) (dotted line) as a function of Δz.

3 Detector-induced asymmetries

Since the asymmetry A_T is expected to be small, we must control possible charge asymmetries induced by the detection and reconstruction of electrons and muons. The strategy in this analysis is first to correct on an event-by-event basis charge asymmetries determined with independent control samples, and then to validate this approach with a sample of single direct leptons from B decays.

3.1 Charge asymmetry correction

The three sources of charge asymmetry in the selection of lepton candidates are

1. the difference in tracking efficiency for positive and negative particles, $\varepsilon^+_{track} \neq \varepsilon^-_{track}$;
2. the difference in particle identification efficiency for positive and negative leptons, $\varepsilon^+_{pid} \neq \varepsilon^-_{pid}$; and
3. the difference in misidentification probability for positive and negative particles, $\eta^+_{pid} \neq \eta^-_{pid}$.

These efficiencies and probabilities are estimated using independent samples (see next sections) on an event-by-event basis and as a function of several kinematic variables x_i of the charged track: the total momentum, transverse momentum, polar angle and the azimuthal angle of the charged track. The numbers of "detected" positive and negative leptons $N^{\pm}_{detected}(\ell)$ are related to the numbers of

true leptons $N^{\pm}_{true}(\ell)$ by the equation:

$$
\begin{aligned}
N^{\pm}_{detected}(\ell) =& N^{\pm}_{true}(\ell) \cdot \varepsilon^{\pm}_{track}(x_i) \cdot \left[\varepsilon^{\pm}_{pid}(x_i) + r(\pi, p^*) \cdot \eta^{\pm}_{pid}(\pi, x_i)\right. \\
&\left. + r(K, p^*) \cdot \eta^{\pm}_{pid}(K, x_i) + r(p, p^*) \cdot \eta^{\pm}_{pid}(p, x_i)\right],
\end{aligned} \tag{2}
$$

where $r(\pi, p^*)$, $r(K, p^*)$ and $r(p, p^*)$ are the relative abundances of hadrons (π, K, and p) with respect to the lepton abundance for a given p^* (the momentum of the track in the CMS). These quantities are obtained from generic $B\overline{B}$ Monte Carlo events, after applying the event selection criteria. To correct for the charge asymmetries, we apply a weight proportional to the ratio $N^{\pm}_{true}(\ell)/N^{\pm}_{detected}(\ell)$, for each lepton in the sample.

3.2 Correction with control samples

3.2.1 Charge asymmetry in tracking

The event selection requires at least 12 DCH hits per track, which can introduce a charge asymmetry in the tracking efficiency. In this analysis, we are selecting tracks with large momentum in the CMS, which implies that the transverse momentum is also large. Therefore, the dilepton sample should be only slightly affected by any charge asymmetry in tracking. To remove this possible bias, we determine separate efficiencies for positive and negative particles. The tracking efficiency, which is dominated by the DCH, is defined as the ratio of the number of SVT tracks with 12 DCH hits divided by the initial number of SVT tracks. These track efficiency correction tables are computed as a function of transverse momentum, polar angle and azimuthal angle in the laboratory frame. The charge asymmetry correction is less than 0.1% on average in the relevant ranges for the lepton tracks.

3.2.2 Charge asymmetry in lepton identification

Since the particle identification efficiencies and the misidentification probabilities are determined as the ratio of the number of events with an identified track over the number of initial events, the efficiency and misidentification probability tables are independent of the tracking efficiency. These tables are computed as a function of total momentum, polar angle and azimuthal angle in the laboratory frame for different control samples:

- The identification efficiencies for the electrons are measured with the combination of two control samples: $\gamma\gamma \to eeee$ and radiative Bhabha events;
- The identification efficiencies for the muons are measured with a control sample consisting of $\gamma\gamma \to ee\mu\mu$ events;
- The misidentification probabilities are determined using control samples of kaons produced in $D^{*+} \to \pi^+ D^0 \to \pi^+ K^- \pi^+$ decays (and charge conjugate), pions produced in $K_S \to \pi^+\pi^-$ decays, one-prong and three-prong τ decays, and protons produced in Λ decays.

For the electrons, the charge asymmetry in the efficiency reaches (0.5–1.0)% in some regions of the lepton phase space. The impact of the charge asymmetry in misidentification is negligible because the absolute misidentification probability for pions is extremely small ($\sim 0.2\%$). However, the Λ control sample indicates a very large misidentification probability for antiprotons with momentum $\sim 1\,\mathrm{GeV}/c$. Such an effect is due to the annihilation of antiprotons with protons in the calorimeter,

which produces a signature similar to that of an electron. The impact of this effect is balanced by the low relative abundance of antiprotons in generic B events. Overall, antiprotons induce a charge asymmetry of order 0.1% and a correction is applied for this effect.

For the muons, the $ee\mu\mu$ control sample shows that the charge asymmetry in the efficiency reaches 0.5%. The fraction of fake pions ($\sim 3\%$) is much larger than in the case of electrons but there is no indication of any charge asymmetry. On the other hand, the kaon misidentification distribution shows a charge asymmetry at the level of (10–20)% due to the difference between cross sections for K^+ and K^- mesons interactions with matter in the range of momentum around $1\,\mathrm{GeV}/c$.

3.3 Validation with single direct leptons

A cross check of the correction for charge asymmetries in the lepton selection is performed with an independent sample that has the same topology and kinematics as the leptons from dilepton events: namely direct leptons from semileptonic B decays. The selection of these events is quite similar to the dilepton selection described in Sec. 2.

The single-lepton charge asymmetry is sensitive to the charge asymmetry due to detection bias but it may also be affected by the real physical charge asymmetry A_T in the dilepton events. In this case, the physical charge asymmetry $A^{physics}_{single}$ can be written as

$$A^{physics}_{single} = D \cdot \chi_d \cdot \frac{1}{1+R} \cdot A_T,$$

where D is a dilution factor due to background (cascade leptons, etc.), χ_d is the B^0 mixing parameter, and R is the fraction of charged B mesons in the sample.[2] The possible bias introduced by A_T is suppressed by more than one order of magnitude and is therefore neglected.

With the 1999–2000 data set, we select roughly 1.5 million electrons and 1.5 million muons. After subtraction of scaled off-resonance data and after applying a correction weight as defined in Eq. 2, we measure the remaining asymmetry as a function of the total momentum (see Fig. 3). For both muons and electrons, the distributions are consistent with being flat. The single-muon charge asymmetry $(-0.35\pm0.17)\%$ and the single electron charge asymmetry $(-0.30\pm0.14)\%$ are consistent with zero. These measured charge asymmetries for single leptons show that the systematic errors related to the muon and electron detection are at the level of $\pm0.35\%$ and $\pm0.30\%$, respectively.

4 Measurement of Re($\boldsymbol{\varepsilon}_\mathbf{B}$)

4.1 Measurement of A_T

Equation 1 is applicable for pure signal (B^0B^0 and $\overline{B}^0\overline{B}^0$ pairs). However, the dilepton events are contaminated by cascade leptons from B^+B^- and unmixed $B^0\overline{B}^0$ events (see Fig. 2), non-$B\overline{B}$ events, and J/ψ decays. Assuming no charge asymmetry in the background and assuming CP invariance holds in the direct leptonic B decays,[3] we can write the measured asymmetry A_T^{meas}

[2] R is the ratio $(b_+^2 f_{+-})/(b_0^2 f_{00})$ where b_+ and b_0 are respectively the semileptonic branching fractions of charged and neutral B mesons, and f_{+-}/f_{00} is the production ratio of charged and neutral B mesons.

[3] In the literature, the equality of the decay probabilities $P(B^0 \to \ell^+)$ and $P(\overline{B}^0 \to \ell^-)$ is usually obtained from CPT invariance in the decay for inclusive production of direct leptons. However, in this analysis, the signal is selected by imposing cuts on the lepton momentum, which is equivalent to considering a partial decay channel. As a consequence, the equality of the partially integrated spectrum for leptons and antileptons requires CP symmetry, which is a stronger assumption.

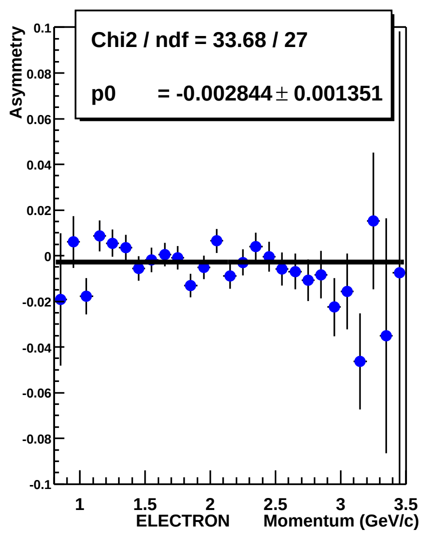

Figure 3: Single direct lepton control sample: charge asymmetries for electrons (left plot) and muons (right plot) as a function of the total momentum.

(see Fig. 4) in terms of the number of events N as

$$A_T^{meas}(\Delta t) = \frac{N(\ell^+\ell^+, \Delta t) - N(\ell^-\ell^-, \Delta t)}{N(\ell^+\ell^+, \Delta t) + N(\ell^-\ell^-, \Delta t)} = A_T \cdot \frac{S(\Delta t)}{S(\Delta t) + B(\Delta t)}, \tag{3}$$

where $S(\Delta t)$ is the number of signal events and $B(\Delta t)$ the total number of background events. The assumption of no charge asymmetry in the background is confirmed by the off-resonance data where the charge asymmetry $(-5 \pm 10)\%$ is consistent with zero. In addition, the charge asymmetry of the events with $\Delta z < 100\,\mu$m, which contain 85% background (cascade leptons from $B^\pm$ and unmixed B^0), is $(1.2 \pm 1.4)\%$ and so is also consistent with zero. Finally, a possible dilution of A_T due to double mistag is neglected because the probability of double mistag is at the level of only 1%. All these assumptions are taken into account in the determination of the systematic error.

Therefore, extraction of a value for A_T requires a determination of the dilution factor $S(\Delta t)/\left[S(\Delta t) + B(\Delta t)\right]$. The dilution factor can be measured directly from the data with the probability density functions (Fig. 2) obtained from the full dilepton sample with the value of Δm_d fixed to the world average value [8]. With this method, the fraction of non-$B\overline{B}$ events is determined from off-resonance data, and the fraction of cascade leptons and the resolution function corrections are measured directly from the dilepton data. In order to benefit in the determination of A_T from the full information provided by Δz, a correction factor for the background dilution $1+B(\Delta z_i)/S(\Delta z_i)$ is applied to each Δz_i bin considered in the fit.

After applying the above correction to the dilepton sample, we measure $A_T = (0.5 \pm 1.2)\,\%$ from a fit to the distribution of the charge asymmetry as a function of Δt (see Fig. 4).

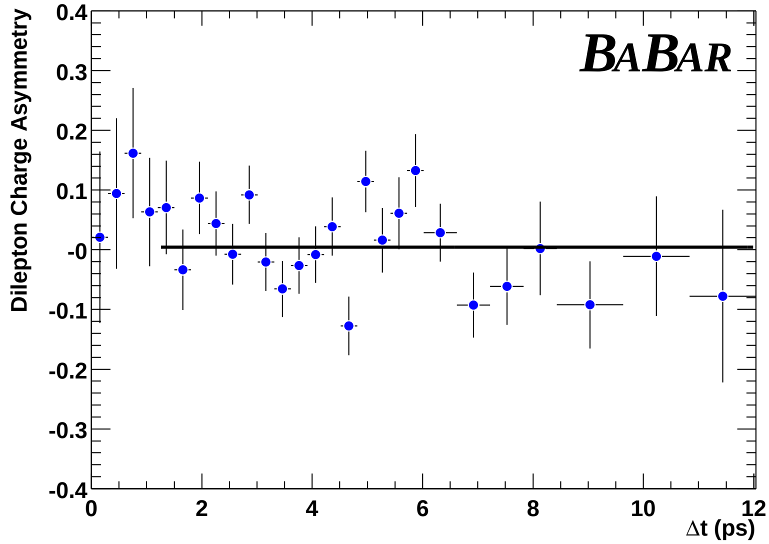

Figure 4: Corrected dilepton charge asymmetry as a function of Δt. The line shows the result of the fit for the same-sign dileptons with $\Delta z > 200\,\mu$m.

4.2 Systematic uncertainties

The detection charge asymmetry is partially corrected by applying an event-by-event weight. We assign the residual asymmetries measured with the single lepton samples (see Sec. 3.3), $\pm 0.30\%$ for the electrons and $\pm 0.35\%$ for the muons, as the systematic errors due to charge asymmetry in detection efficiencies. After taking into account the dilution factor, the total systematic error related to the charge asymmetry in the detection efficiencies are $\pm 0.5\%$ and $\pm 0.6\%$ for electrons and muons, respectively.

The charge asymmetry of $(-5 \pm 10)\%$ measured with the off-resonance data leads to a $\pm 0.7\%$ uncertainty on the A_T measurement, determined from the statistical error $\pm 10\%$. In a similar way, the charge asymmetry of $(1.2 \pm 1.4)\%$, obtained with the events satisfying $\Delta z < 100\,\mu$m, results in a $\pm 0.9\%$ uncertainty on A_T. If we assumed CP invariance in the decays producing the cascade leptons, this uncertainty would vanish.

The other systematic uncertainties are due to the background dilution correction. This correction is measured with the data from the full dilepton sample with the value of Δm_d fixed to the world average value [8]. The uncertainty on the ratio B/S leads to a $\pm 3\%$ multiplicative error on A_T, which is negligible.

All sources of systematic uncertainty are listed in Table 1. The total systematic uncertainty is $\pm 1.4\%$.

5 Conclusions

With the 1999–2000 data consisting of 20.7 fb^{-1} on-resonance and 2.6 fb^{-1} off-resonance, we have selected 20,381 same-sign dilepton events with a NN approach and a rejection of the cascade leptons

Type of systematic error	$\sigma(A_T)$(%)
Electron charge asymmetry in the detection	0.5
Muon charge asymmetry in the detection	0.6
Non-$B\overline{B}$ background charge asymmetry	0.7
$B\overline{B}$ background charge asymmetry	0.9
Total	1.4

Table 1: Summary of systematic uncertainties on A_T.

from charged B or unmixed neutral B events based on the Δz information. Charge asymmetries in the lepton selection are corrected event-by-event and the correction method is confirmed with the single lepton sample. We have measured a same-sign dilepton asymmetry of $A_T = (0.5 \pm 1.2 \pm 1.4)\%$. From Eq. 1, the A_T asymmetry gives a preliminary result for the T and CP violation parameter ε_B:

$$\frac{\mathrm{Re}(\varepsilon_\mathrm{B})}{1+|\varepsilon_B|^2} = (1.2 \pm 2.9 \pm 3.6) \times 10^{-3}.$$

This preliminary measurement is the most stringent test of T and CP violation in $B^0\overline{B}^0$ mixing to date and is consistent with previous measurements [9] of $\mathrm{Re}(\varepsilon_\mathrm{B})/(1+|\varepsilon_\mathrm{B}|^2)$. With the formalism [4] using the complex parameters p and q, this measurement of A_T gives $|q/p| = 0.998 \pm 0.006 \pm 0.007$.

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